

LA PROGETTAZIONE DI UNA MODERNA CENTRALE ELETTRICA: LA CENTRALE DI VOGHERA ENERGIA

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SOMMARIO

Foster Wheeler Italiana (FWI) sta realizzando per Voghera Energia (VE, gruppo Electrabel) una centrale a ciclo combinato da 400 MW in configurazione monoalbero nel territorio del comune di Voghera (PV).

La centrale è progettata per 50 avviamenti all'anno con una automazione spinta; in particolare tutte le operazioni relative alla messa in marcia e alla fermata della centrale saranno effettuate dalla sala controllo senza l'ausilio di personale in campo.

La centrale, che opererà in un ambiente rurale, è vincolata al rispetto di limiti di emissioni estremamente ridotti, in particolare per quanto riguarda l'impatto acustico.

Il presente articolo descrive l'approccio ingegneristico alle problematiche sopra elencate e la scelta tecnica finale.

SUMMARY

The start of the Energy Stock Market as well as transfer to the local entities (i.e. Regioni) of the responsibilities for the energy planning introduced new challenges for tackling by the designer.

Foster Wheeler Italiana (FWI) is erecting for Voghera Energia (VE, Electrabel/ACEA group) a combined cycle power plant (CCPP) in the neighbourhood of the town of Voghera, 50 kilometers south of Milan.

The CCPP is designed with a high degree of automation: in particular, all the start-up operations are carried out from the control room, with no rovers at site.

The plant is located in a rural area (even though industrial development is planned) so as strict noise limits have been applied.

This paper depicts the approach to the above issue and the engineering activities which led to the final technical solution.

1. INTRODUCTION

The Voghera Energia 400 MW Combined Cycle Power Plant (CCPP) presently under construction, is the first power plant which has obtained the permit for construction and operation after the liberalization of the electric market in Italy.

The plant is a single shaft combined cycle, based on V-94.3A2 gas turbine manufactured by Ansaldo Energia on Siemens technology, with a FWI three pressure level Heat Recovery Steam Generator with reheat.

This article depicts some key aspects of both the project development and the plant design, which have contributed to the success of the initiative.

2. HISTORY

The milestones of the project history are the following:

- 1st presentation of the project background and plant main features : September '99
- Request for the Environmental Impact Assessment Procedure and notification to the Public : May '00
- Addendum to the Request for the Environmental Impact Assessment due to the implementation of an Improved plant design and new press notification: October '00
- Establishment of the Project Company (Voghera Energia) : November '00
- Issue of the Environmental Impact Assessment by the Ministry of the Environment: January '02
- Issue of the Authorization to the Erection and operation by the Ministry of the Industry: April '02
- Issue of the Building Permit: August '02
- Contract signature and start of the engineering activities: August '02
- Start of construction : November '02
- Commercial operation : February '05 (exp.)

3. PROJECT DEVELOPMENT

FWI was appointed as leader of the project development activities on behalf of the project company

The authorization procedure followed the rules set forth by the DPCM 27-12-88-, Attachment 4 governing the Environmental Impact Assessment and the general rules concerning the atmospheric emissions, the planning permit etc.

After the promoter has filed the notice in order to apply for the Environmental Impact Assessment, the appraisal phase started; the steps of this phase as well as the involved parties are summarized with the following Figure 1.

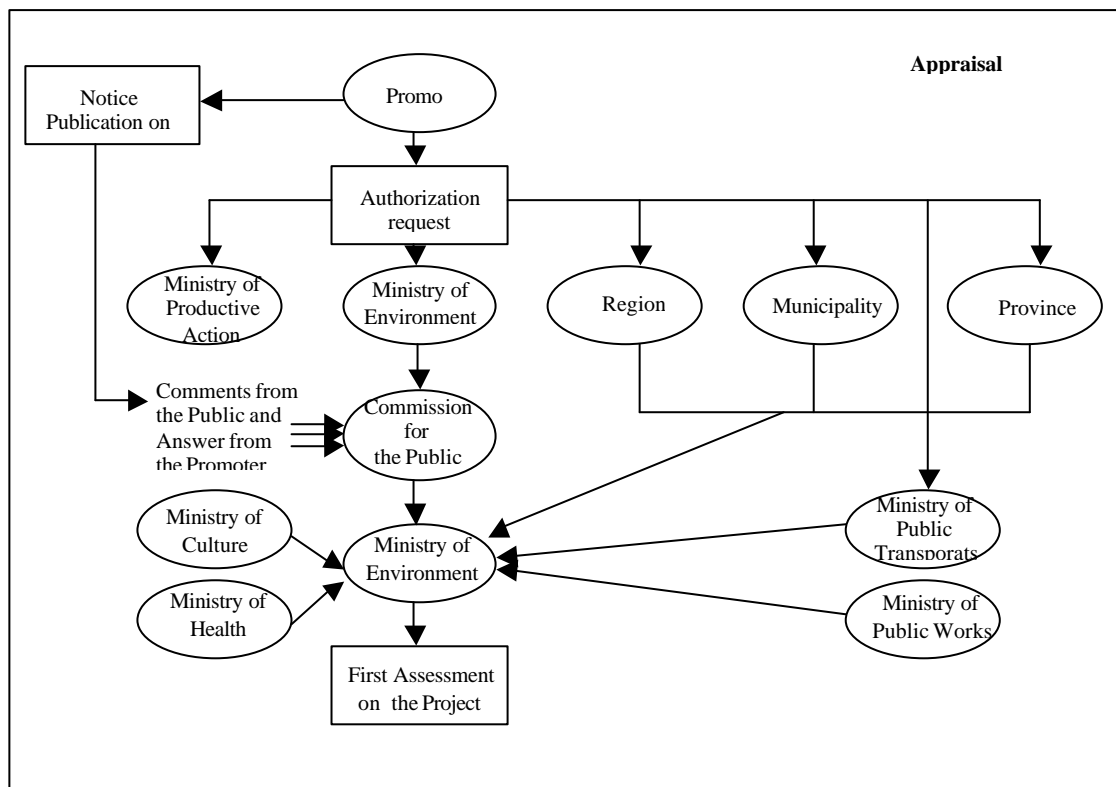


Figure 1: framework of Environmental Impact Assessment phases

The winning aspects, which led to a successful conclusion of the project development are summarized below:

- 1) Early involvement of the local Utility Company (ASM Voghera, active in the water/power/gas supply business as well as in the public transports) as local facilitator
- 2) Careful selection, together with the local entities, of the site. In fact, although the plant is a “greenfield facility”, the site presents a number of significant advantages:
 - It is adjacent to a paper mill, requiring heat and electric power for their process. LP steam will be supplied from the facility to paper mill which will switch-off their old low efficiency boiler thus eliminating their emissions. In addition there is a provision for the direct supply of electric power from the facility, helping the profitability of the paper mill operation, thus benefitting the local economy
 - It is very close to the high voltage transmission line, thus requiring a very short connecting line and minimizing the impact on the area
 - It is very close to the gas pipeline (which actually crosses the site), again minimizing the impact for the connection to the natural gas network
 - It is close to the area where the master plan foresees the establishment of industrial and infrastructure development
- 3) Selection of a “state of the art” plant architecture and equipment, aiming to high efficiency and minimal environmental impact for both NOx/CO and greenhouse gases emission
- 4) Careful architectural design and landscaping with only 1/3 of the area actually occupied by the plant

- 5) Single fuel selection (natural gas)
- 6) Minimal use of natural resources (i.e. water) through the use of an air cooled condenser.

4. PLANT DESCRIPTION

The plant is composed by the following main equipment

- A 265 MW gas turbine, model V-94.3A2 manufactured by Ansaldo Energia (AEN) based on Siemens technology, natural gas fuelled, with Dry Low Nox burners (DLN)
- A three pressure level horizontal Heat Recovery Steam Generator (HRSG) with reheat, manufactured by Foster Wheeler Italiana, designed for pure recovery operating mode, equipped with an integrated 80 m tall stack.
- A 130 MW tandem compound single flow reheat steam turbine, manufactured by Ansaldo Energia, consisting of a high pressure section and a combined intermediate and low pressure section with axial discharge. The ST is connected to the generator through a clutch, so as it can be easily disconnected in case of trip and during the start-up/shut-down.
- A 470 MVA generator, manufactured by Ansaldo Energia, hydrogen cooled.
- An Air Cooled Condenser (ACC), single row technology, manufactured by GEA, composed by 21 bays arranged in three parallel rows. Each row is composed by five condensing and two deflegmating modules.

The deflegmating modules are coupled to two speed fans.

- A 490 MVA step-up transformer, two windings 400/20kV, oil immersed, manufactured by Siemens.
- The balance of the plant including
 - Air cooled machinery cooling water
 - Well/service water
 - Demineralized water
 - Instrument/Plant air
 - Natural gas metering and reduction
 - Auxiliary boiler
 - Waste water treatment

The plant performances and main technical figures are:

Net Electric Power Production	382 MW
Net Heat Rate	6464 kJ/kWh

Steam conditions (at ST inlet)

HP	117.5 bar & 559°C
RH	31.17 bar & 559°C
LP	4.8 bar & 234°C
Exhaust	80 mbar

5. CCPP CONTROL SYSTEM

The Voghera CCPP is managed by a Distributed Control System (DCS) which is the frame of the control, protection and automation system.

Other important pieces of this system are:

- Gas and steam turbine control systems (GTCS and STCS)
- Emergency shut-down system (ESD)
- Electrical Management System (EMS)
- Microprocessor based systems for packages

5.1 Steam and gas turbine control systems

These systems are included in the relevant packages.

This is obvious as the control algorithms and parameters are proprietary and an essential part of the Vendor's know-how.

Such systems perform the supervision, control and protection of the rotating equipment as well as of the ancillary systems, managing all phases of the operation (start-up, operation, shut-down, emergency) displaying all the information and commands on dedicated operator station which are separated from the ones of the DCS.

5.2 Distributed Control System

The DCS performs the command, control and supervision of all the equipment directly connected as well as supervision and coordination of all packages which are equipped with independent control systems (and then also of the gas and steam turbines and the generator).

It is a complex system, organized hierarchically, whose function is to enable the plant control and supervision from a centralized station.

The system architecture is represented in Figure 1, which shows the three typologies of modules, organized in the three hierarchical levels and connected through the system and/or transmission/communication system:

- 1st Level: data acquisition, regulation and control modules
- 2nd Level: operator interface, regulation, control and communication modules
- 3rd level: performance evaluation module

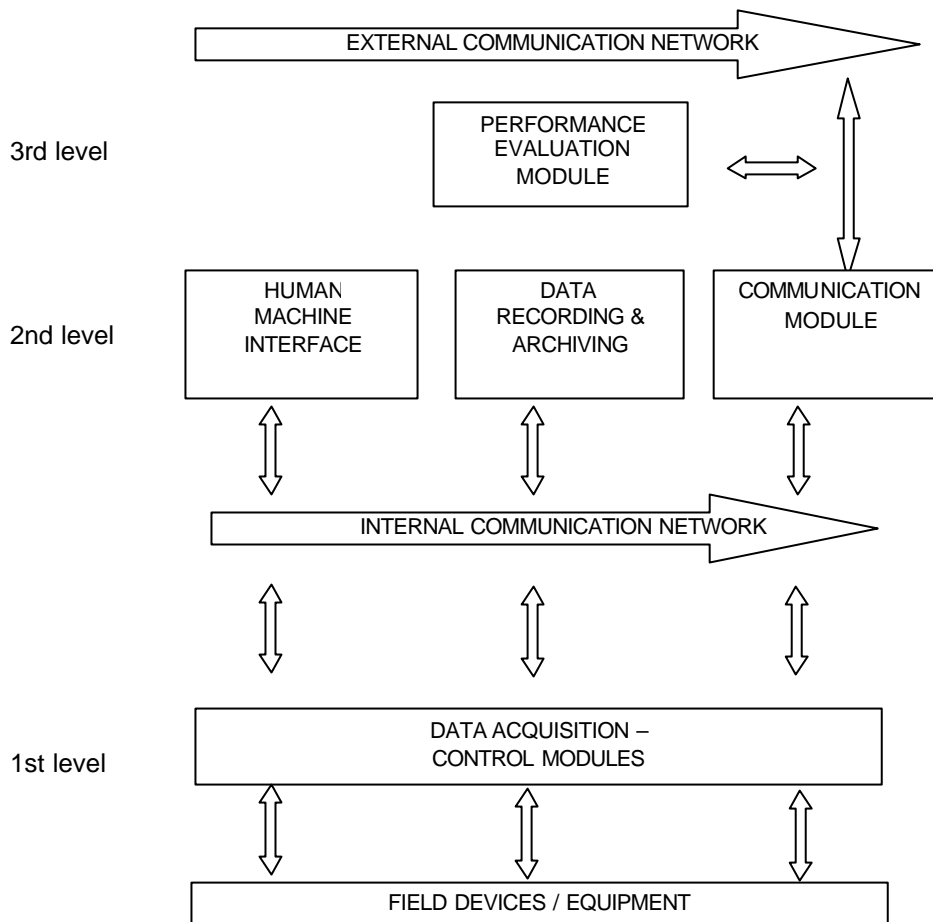


Figure 1: DCS architecture

A key aspect is the integration between the DCS and the ST/GT control systems. Given that generally the start-up and shut-down sequences are managed by the DCS, it has to be chosen from which station the operating parameters of the machines will be accessible.

Typically, different scenarios can show up:

- a) all operating parameters are accessible from the relevant turbine control system only
- b) all operating parameters are accessible from both turbine control system and DCS HMI stations
- c) only selected operating parameters of the turbines are transferred from the turbine control system to the DCS, while other parameters are accessible from the machine operator station only.

The selected option for the Voghera plant was option c).

This solution has been judged as the most effective in ensuring a high degree of automation and supervision capability without an excessive complication of the system.

The most important commands/status signals are exchanged on hardwired connections, while less important signals are exchanged by means of redundant link based on Ethernet OPC protocol.

5.3 Emergency Shut-down System

All the circuits which have been identified as critical for personnel and/or equipment integrity have been designed to be independent.

Safety analyses (HAZOP, fault tree etc.) have been applied to determine all the possible critical events, their probability and then the level of severity of the application.

Further to those analyses, the IEC61508 guidelines have been used to determine the type of system to be adopted (Safety related Programmable Electronic System – PES).

A fault tolerant, fail safe, SIL grade 3 system, certified by specialized entities, has been installed; its main characteristics are:

- redundant equipment (2oo3)
- line monitoring and signal validation
- advanced diagnostic
- protection of the critical program through “read-only memory”.

The interface with the plant DCS is realized through redundant link based on Ethernet OPC protocol with “time stamp” function in order to guarantee the correct information of the occurrence of the event for the Sequence of Events Recorder (SER) incorporated in the DCS.

5.4 Electrical Management System

The EMS is integrated in the DCS and is designed to coordinate the equipment for the control, protection, supervision of the electrical network, and in particular those of the HV bay, of the transformers and of the MV/LV distribution network.

These are realized with a microprocessor technology which are able, among the others, to elaborate the parameters necessary for the management of the electrical network.

The ability of the microprocessor to elaborate data allows for instance:

- the sequence of events recording
- centralized management for the monitoring and setting of protections and measures
- recording of the electrical transients

5.5 Integration among the Control Systems

As already mentioned, the gas and steam turbines have their own proprietary control systems.

The integration of the plant and equipment control systems is a key aspect, especially considering the operators requirements for the management of a modern power plant (e.g. limited number of operators, all routine operating activities and electrical network supervision from the control room).

The integration of the control functions is required both for the continuous controls and for the sequenced manovres.

A typical example of the first group is the steam pressure control (for each level).

Almost invariably, the CCPP's are operated in "sliding pressure mode", i.e. the pressure is left free to fluctuate between an upper and lower limit according to the plant load.

In addition, a tracking function is implemented in the DCS with the scope of limiting the rate of change of the pressure/temperature in the steam drum.

Both functions are managed through the steam turbine's bypasses (control algorithms in the DCS) and the ST admission control valves (control algorithm and field elements in the STCS – Steam Turbine Control System).

Another example is the rate of change of load for the GT during the plant start-up, which is lower than the standard preimposed rates of the gas turbine.

This is accomplished by a continuous change by the DCS of the load set point of the gas turbine until 50% of the base load.

An example of the second group is the exchange of status signals of the various equipment/systems during the start-up.

For instance, the pulling of vacuum in the condenser is subject to the condition that the steam turbine is steam sealed and under turning gear.

Other exchanges of status signals are:

- transfer of steam pressure control from the bypass to the steam turbine
- management of the steam headers/steam turbine vents and drains

5.6 Plant automation

The plant automation level has been defined considering the requirements of the management of the modern merchant plant, aiming to maximizing the performance and minimizing the operating costs.

In particular the plant operation shall be controlled by a limited number of shift operators (2 for Voghera plant).

In particular the start-up/shut-down sequences are managed by the DCS, with a limited number of manual commands and supervision left to the operator.

The result is a "macro-sequence" composed of functional steps which, to their turn, perform the action relevant to the start-up of a part of the plant (typically an auxiliary system) or a "homogeneous" part of the sequences (for instance: the heat up of the HP steam/water circuit).

The logic link between the various subsequence as well as the correct time slot allowed for each subsequence have been checked by means of a specific engineering tools during the home-office activities, with the aim of simplifying and shortening the field activities during the commissioning and start-up of the plant.

6. NOISE CONTROL

Right from the beginning of the project we realized that the environmental acoustic impact should have been a critical matter for the design of the Power Plant.

The very low pre-existing noise levels recorded during the basic engineering at the receptors potentially affected by the acoustic emissions of the plant, together with the relatively short distances from them to the Power Plant, made us aware of how critical this aspect was for the

project. In such a context the controlling case is the applicable community noise regulation asking for a maximum increase of the residual noise levels at sensitive receptors during night-time by no more than 3 dB(A). This differential criterion does not apply when, whether is the increase generated by the plant, the environmental noise levels inside inhabited rooms with open windows are lower than 40 dB(A), since the acoustic disturbance is considered as negligible. In short, the power station acoustic emission is so limited to almost not modify the acoustic climate at the receptors.



Figure 2: View of the Power Station under construction taken from one receptor

During the permitting phase of the project a calculation model was prepared to predict the noise levels emitted by the power station. The Preliminary Noise Study gave a first definition of the limitations to be adopted for the equipment emitting noise and the buildings containing them. We took particular care of the items directly emitting into the environment such as the air-cooled condenser, the heat recovery steam generator, the boiler feed water pumps and the gas turbine air intake. The study was also supported by careful investigations, with equipment Suppliers and acoustic Consultants, having the scope to confirm that the acoustic emission limits allocated to the plant components were really achievable considering the noise control measures available in the industry. The Environmental Impact Assessment issued by the Authority did not allow any relaxation with the community noise regulations: it prescribed an acoustic monitoring at the receptors just before the plant start-up and later on with the Power Station at full load.

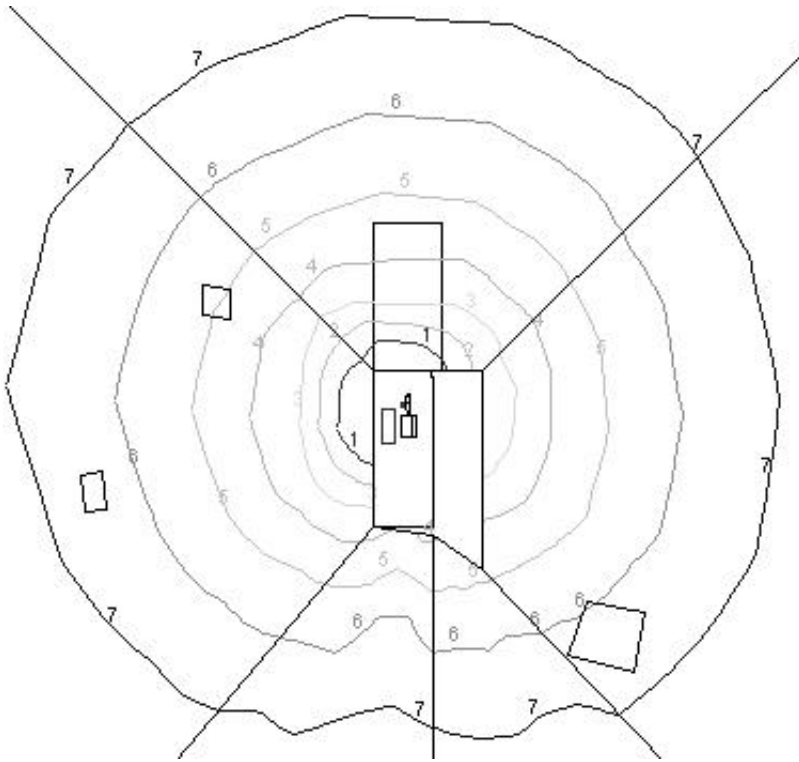


Figure 3: emitted noise levels preliminarily calculated

Next steps were:(a) A room acoustic study was developed to acoustically define the characteristics of the technical building containing the (acoustically enclosed) single shaft power train, (b) a dedicated study was carried out to achieve a proper acoustic design of the heat recovery steam generator walls and stack outlet (in addition to the heavy walls and stack silencer, later on it has been also planned to acoustically screen all the HRSG inlet duct with sound absorbing barriers) and (c) a thorough examination to understand the acoustical state of the art of the air cooler condenser noise emission was pursued.

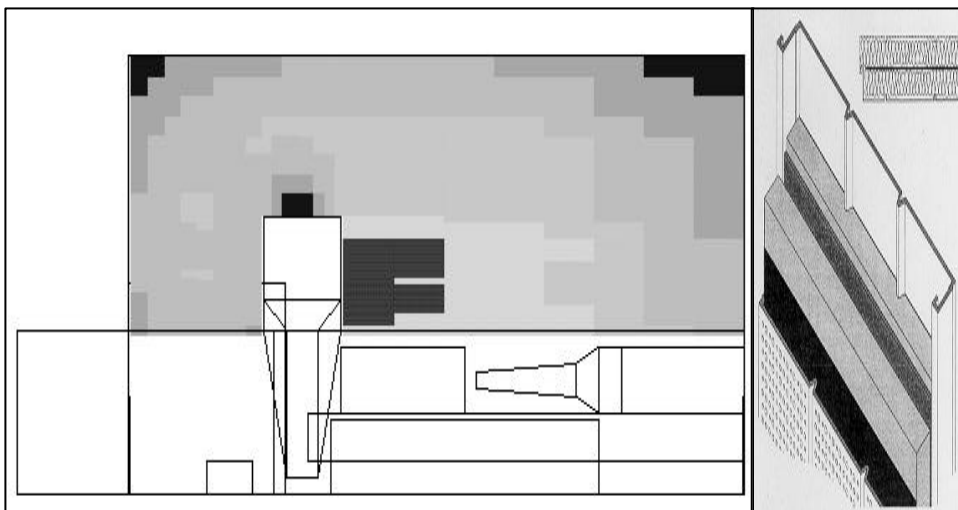


Figure 4: calculated surface sound pressure levels on the inner side of a portion of the technical building with the associated exploded view of the selected panel

The Equipment Noise Control specification was prepared and issued. It substantially took into consideration the Preliminary Noise Study and the prescriptions reported on the Environmental Impact Assessment (not only asking for an acoustical monitoring at the receptors). The studies and investigations previously developed were evidently considered during its preparation. The specification was attached to the technical documentation for the purchase of the equipment considered as sources of noise, constituting therefore a contractual obligation for the equipment Suppliers. When the operating conditions of the equipment could be simulated, the sound test has been requested before the equipment leaves the respective Supplier workshop.

The acoustic engineering was always in touch with the project team, so as to identify those variations having an acoustic impact and consequently suggesting the needed measures not to exceed the limits. The acoustical balance of the production unit was constantly kept under control and brought it up-to-date by the light of changes occurred during the detailed design and the acoustical data obtained by the equipment Manufacturers. The acoustical information received by the Manufactures of some equipment was forwarded to other Vendors so as to put them in a position to properly design considering also the emission of those parts of their supply resulting a propagation path of the noise generated by other plant components. The air-cooled condenser that, in addition to its own emission (fans units, vacuum skid, valves, condensate pumps and relevant piping), receives noise from the steam turbine exhaust, and its bypass system, and radiates it into the outdoor environment through the steam exhaust duct, the expansion joints and the steam distribution constitutes an example of such a combination. With regard to this aspect the ACC Supplier decided to reduce the exhaust steam duct induced acoustic emission by means of an acoustical insulation system specifically realized.



Figure 5: external steel cladding for a portion of the acoustical insulation system realized for the exhaust steam duct



Figure 6: view of one ACC fan manufactured by the english Howden declaring its SX cooling fan as “the world's quietest, by far” (to not nullify its acoustical performance all the ACC electric motors drivers and gear-boxes have been decided to be acoustically enclosed)

The single shaft power train was directly committed by the Client. The acoustic emission declared by the SSPT Supplier for two outdoors items associated with it (GT Air Intake, Fin Fan Cooler) was considered by us as too excessive. The advanced phase of the design of these components, together with difficulties on changing the contractual limit by this time specified, did not allow for modifications at these sources (a most performing silencer into the air duct, low-noise fans units). It was decided to operate on the near-field acoustical path by means of sound absorbing barriers and acoustical louvres. Specific studies were developed to acoustically design the barriers and the louvres carefully considering the estimated air flow pattern in their immediate vicinity. These components Suppliers together with the SSPT Vendor were requested to take part in it making a review of the barriers to make sure that the installation of the barriers would have led to negligible effects both in terms of pressure losses and induced distortions of the natural flows patterns, hence potential performance losses.

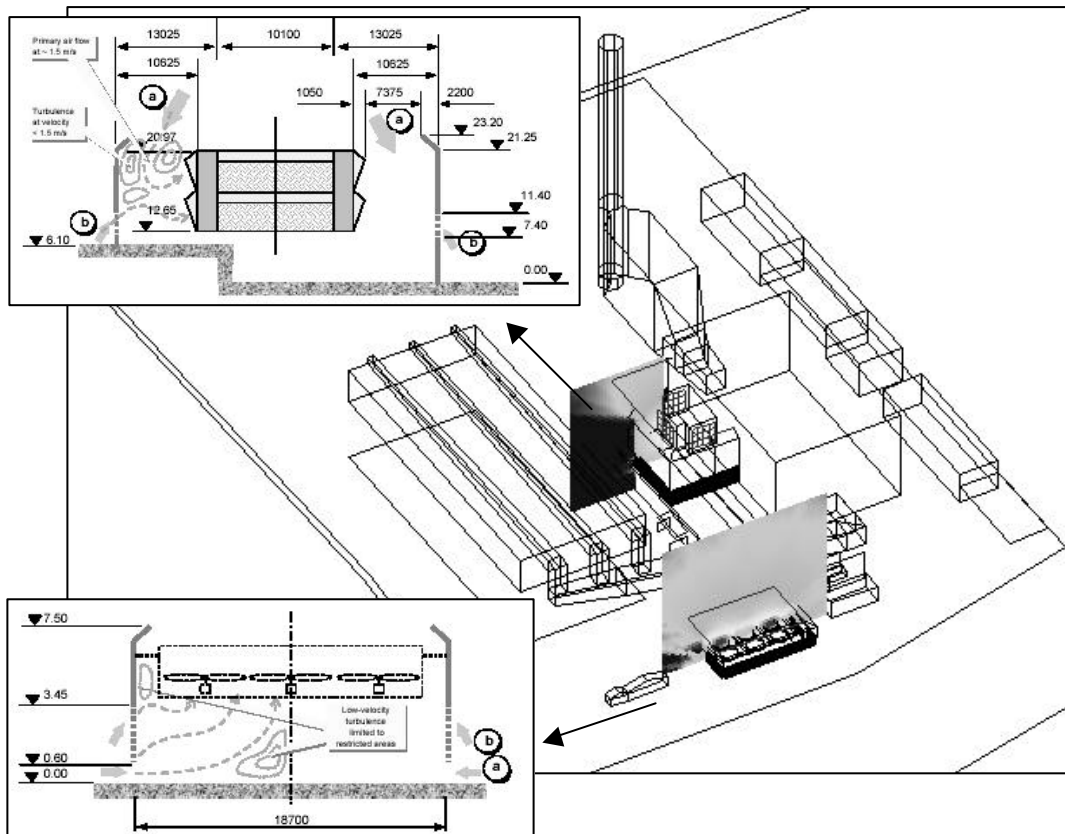


Figure 7: calculations for the acoustical and hydraulic design of the barriers around the SSPT outdoor items

Basing on what above reported, it is obvious that noise control measures have been planned for the other contributors of the Plant: most of the outdoor (and not only the outdoor ones) rotating equipment are acoustically enclosed with silencers on each opening for the air ventilation (e.g. the boiler feed water pumps but also the heat ventilation air conditioning equipment) and, where necessary, special low-noise control valves and/or acoustical insulation for the downstream pipes have been planned. Also the equipment emitting noise during operational transitory phases, such as the Power Plant start up and shutdown - but also during emergencies, have been silenced. For instance this is the case of the steam turbine by pass system, auxiliary boiler, most of the steam vents to atmosphere and the emergency diesel generator. Also the construction phase of the plant, as well the pre-commissioning one, were subjected to noise control.

7. CONCLUSION

The design of the VE CCPP posed to the Engineer a number of specific challenging technical issues which are partly due to the new rules of the electric market and partly to the specific site characteristics.

These issues were solved through a close cooperation among the various disciplines involved in the plant design since the beginning of the project.

This approach, opposed to the one of putting together packages designed by different vendors, judged essential for the success of the project.